Journal Tri. Math Soc. Volume-14 (2012) 16-23

Human Eye Detection using Harris Corner Detector

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Abstract: *In this paper we have focused on human eye detection using morphological operator and Harris corner detection method. In our approach we have first generated a unique background using dilation (morphological) operation, so that the corner detection algorithm doesn't detect any corner in the background i.e. outside the face. Dilation is a powerful operator for extracting features from an image (e.g. filling holes and broken areas). Here it is used to remove the light objects from the background. After that, we have used a corner detection technique called the 'Harris corner detector', which is an interest point detector and is strongly invariant to scale and illumination variation. Then, the intermediate distance between obtained corners are measured and compared with the predetermined distance between the two corners of an eye. The measured distances those come within a considerable range of the predetermined distance, ensures the detection of an eye. After the eye is detected, we extract both the left and right eyes separately and store them in the Eye Database. ORL Face Database has been used for this work.*

1. Introduction

Human face recognition has been largely investigated for the last two decades. It has a wide application field ranging from the commercial to the security one. For recognizing a human face, fiducial point estimation may be one of the essential tasks. A mark, or one of several marks, visible in the field of view of an optical instrument, used as a reference or for measurement, is known as fiducial point. There are several fiducial points in human face. Eyes are the most prominent features on the face. So, we can consider eyes as one of the most important fiducial points. The prominence of eyes with respect to the other fiducial points is due to several reasons:

- Eyes are a crucial source of information about the state of human beings. The shape, size, and color of the eyes provide hints in recognizing individuals; The eye movement may reveal "interest", or "attention" of a person, and it may contribute to recognize his/her emotional state.
- Faces contain two eyes (if not occluded) that have in general a very similar appearance, so they can be searched simultaneously with the same technique.
- The eye appearance is less variant to certain typical face changes. They are unaffected by the presence of facial hair (like beard or mustaches) and are almost unaltered by small in-depth rotations of the face (though they look closer to each other due to the perspective change), while the nose appearance greatly changes.

- The accurate eye localization permits to identify all the other facial features of interest.

There are several approaches developed by different researchers to detect eyes from human face. G.C. Feng et al. present the variance function which is used to detect eye location & shape. It is completely a new approach [1]. Chris Harris et al. present Image edge filtering for 3D interpretation of image sequences using feature tracking algorithms. A combined corner and edge detector based on the local auto-correlation function is also used [2]. Mohammadreza Ramezanpour et al. proposed a new algorithm. Firstly the face region is extracted from the image by skin-color information. Secondly horizontal projection in image is used to obtain the eye region [3]. Jyoti Malik et al. proposed Harris Corner Detector as a corner detection technique to extract palm print features. Liu wen yu et al. proposed the morphological skeleton which is implemented by fast corner detection algorithm. This technique is completely different from chain code based corner detection algorithm [4]. Cui Xu et al, proposed a eye corner detection method based on schematic features which are abstracted from the structures and appearance and characteristics of the canthus. In this proposed method after detecting the face the eye window is extracted from the face [5]. Waldir S. S. J´unior et al. presents the discriminative filtering technique performs pattern recognition using a two-dimensional filter. It has a closed-form design, based on the pattern and the statistics of the image set. Here, they investigate the use of discriminative filtering for detecting fiducial points in human faces [6]. Paola campadelli et al. presents an algorithm for the automatic detection and description of facial features in 2D color images of either frontal or rotated [7]. Stefano Arca et al. present a method of automatic face detection system on color images after having localized the face and the facial features, it determines facial fiducial points, and characterizes them applying a bank of Gabor filters which extract the peculiar texture around them, they didn't use rotated images [8].

In this paper, we have focused to detect human eye using Harris corner detector after creation unique background by morphological operator (dilation and erosion).

This paper is organized as follows: system overview has been given in Section 2, which includes the description of unique background creation and proposed corner detection technique. Section 3 shows the distance analysis and experimental results using ORL Face Database. Finally, the conclusion and future work is given in section 4.

2. System Overview

The complete system and implementation steps are described with a block diagram shown in Figure 1. At first, we have applied a morphological operator which ensures that no corners will be detected in the background of the input face images. After that, Harris corner detector has been used to detect the corners on the images. After corner detection, we have done manual analysis to find out the possible range of distances between the detected eye corners and used it as the predefined distance. Then, we have searched for the eye corners by measuring the distances between the detected corners and comparing them with the predefined distance. After the separation of the eye corners from the other corners, the eye region was extracted and stored in the eye database.

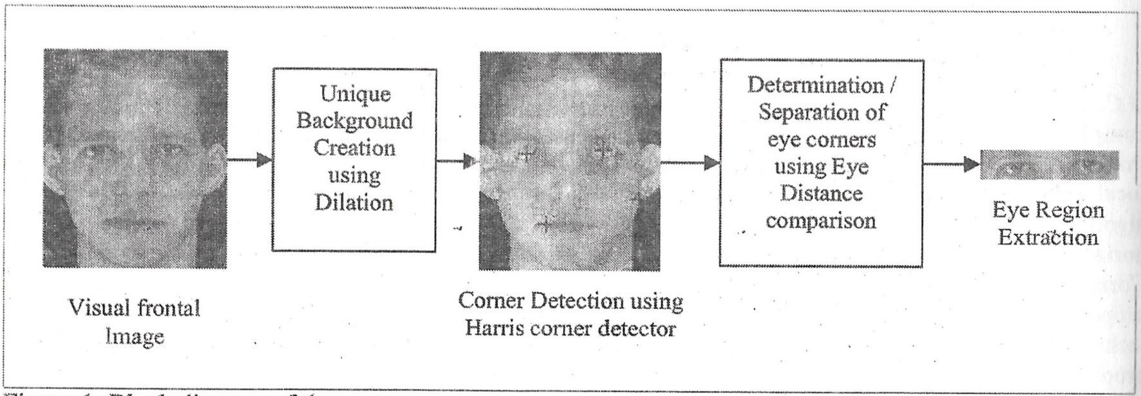

Figure 1: Block diagram of the system.

2.1. Unique Background Creation

In face images, it may happen in some cases that some background light is present. Presence of background light may create problem in the corner detection process as the corner detection method will detect the corners from the whole input image i.e. from both the face region as well as the background of the face also. Therefore, to eradicate the possibility of getting any unwanted corner from the background, it becomes essential to first generate a unique background before starting the detection of corners. For this purpose, the 'dilation' morphological operation has been applied in this work.
Morphology is a broad set of image processing operations that apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbours. The most basic morphological operations are dilation and erosion. In this paper, we have applied dilation operation to generate the images with unique background. Dilation is one type of operation that grows or thickens objects in an image [9]. In this operation the value of the output pixel is the maximum value of all the pixels in the input pixel's neighbourhood. For e.g. in a binary image, if any of the pixels is set to the value 1, the output pixel is also set to 1. In our work we have applied dilation operation on gray scale images. Mathematically, dilation is defined in terms of set operation. The dilation of A by B, denoted $A \oplus B$, is defined as:

$$A \oplus B = \{z \mid (\hat{B})_z \cap A \neq \emptyset\}$$

where, Ø is the empty set and B is the structuring element. In words, the dilation of A by B is the set consisting of all the structuring element origin locations where the reflected and translated B overlaps at least some portion of A.
The image samples shown in Figure 2 reveal the fact about how application of dilation operation has generated the unique background; as a result of which it has been possible to restrict the corner detection algorithm from detecting any corner in the background. In this figure, corner detection algorithm has been applied on the same image, but the only difference is that, the algorithm has been applied directly on the gray scale image in case of (a) and in case of (b) the algorithm has been applied after applying dilation operation on the gray scale image.

2.2. Corner Detection

A corner is defined as the intersection of two edges. A corner can also be defined as point for which there are two dominant and different edge directions in a local neighbourhood of the point [11]. An maximum or minimum, line endings, or a point on a curve where the curvature is lo main advantages of a corner detector is its ability to detect the same corner in multi under conditions of different lighting, translation, rotation and other transforms.

The Corner Detection block finds corners in an image using the Harris corner d eigenvalue, or local intensity comparison method. The block finds the corners in the pixels that have the largest corner metric values [3]. A simple approach to corner det using correlation, but this gets computationally very expensive and suboptimal.

Harris Corner Detector is one of the promising tools to analyze the corner points. autocorrelation of image intensity values or image gradient values. The gradient co given by:

$$M = \begin{pmatrix} A & C \\ C & B \end{pmatrix}$$

Where,

$$A = (I_x)^2 \otimes w$$

$$B = (I_y)^2 \otimes w$$

$$C = (I_x I_y)^2 \otimes w$$

I_x and I_y are the gradients of the input image, I in the X and Y direction, respect $\otimes$ denotes a convolution operation. The coefficients have been used for separabl parameter to define a vector of filter coefficients. The block multiplies this vector of transpose to create a matrix of filter coefficients, w.

The Harris corner detection method avoids the explicit computation of the eigenval squared differences matrix by solving for the following corner metric matrix, R:

$$R = AB - C^2 - k(A+B)^2$$

The variable k corresponds to the sensitivity factor. We can specify its value using the (0<k<0.25) parameter. The value of k has to be determined empirically, and in this used the value 0.04. The smaller the value of k, the more likely it is that the algorith corners. On the basis of R the pixels are classified as follows:

$R > 0$: Corner pixel, $R \sim 0$: pixel in flat region, $R < 0$: Edge pixel

(a)

(b)

(b)

3. Experimental Results and Discussion

3.1. ORL Face Database

There are 10 different visual images of each of 40 distinct subjects. For some subjects, the images were taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses) [10]. All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position (with tolerance for some side movement). The size of each image is 92×112 pixels, with 256 grey levels per pixel.

3.2. Discussion of Experiment Results

After the corners have been detected, our first task is to find out the eye corners; so that we can extract the eyes from the face image. For finding out the eye corners, we first need to find out the lower and upper limits of the distance between the right and left eye corners. For this purpose, manual distance calculation has been done over 10 images of 10 different classes. We have used the 'data cursor' operator of Matlab, which gives the (x, y) coordinate values of the eye corner pixel, on selection of the pixel. An example of the process is shown in Figure 3. After getting the coordinate values of the two eye corners, the row and column distances have been measured. If we consider the coordinates of the two eye corners as (r_1, c_1) and (r_2, c_2), then the row distance (R_d) will be $|r_2 - r_1|$ and the column distance (C_d) will be $|c_2 - c_1|$. All these coordinate values, along with R_d and C_d measured for the 10 different images of 10 different classes are shown in Table 1. From the table it can be seen that the maximum and minimum values for R_d is 2 (R_{dmax}) and 0 (R_{dmin}) respectively and for C_d it's 38 (C_{dmax}) and 26 (C_{dmin}) respectively. These two values of C_d have been used as the limits or as the distance range for eye distance. All these pixel coordinates, row wise distances and column wise distances are shown in Table 1.

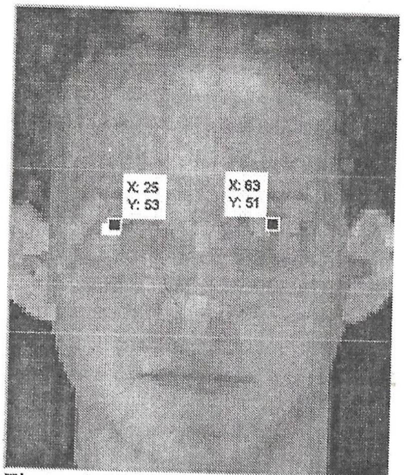

Figure 3. The X and Y coordinate values of the eye corners.

Table 1. Manually calculated row and column distances of the eye corners.

Class	Training image	Pixel coordinate				Distance by coordinate (pixel)	
		Left eye		Right eye			
		c_2	r_2	c_1	r_1	$\|c_2 - c_1\|$	$\|r_2 - r_1\|$
1		63	51	25	53	38	2
2		66	56	31	54	35	2
3		63	53	30	53	33	0
4		59	57	29	57	30	0
5		66	54	31	53	35	1
6		62	48	26	46	36	2
7		58	58	32	59	26	1
8		65	64	30	64	35	0
9		65	39	32	40	33	1
10		68	53	32	53	36	0

As per Table 1, we now know the possible range of the column distance between the two eye corners. For automatic determination of the eye corners, we have used the maximum row distance as the range for selecting the corners which fall within a horizontal region of the height of R_{dmax}. Then the column wise distance is measured between each of the two corners of that region. If any of the distances come within the range of C_d, (i.e. from C_{dmin} to C_{dmax}) then we consider those two corners as the eye corners. Testing images have been chosen from the same 10 classes which were used for training i.e., for manual distance calculation. But, we have selected only the frontal and straight images available in each of

2. Results show that eye detection was successful for 31 images, which implies that eye detection rate is 77.5%.

Table 2. Testing results.

Class	No. of testing images	Eyes detected properly	Eye detected, but with other parts	Not detected	Total no. of testing images	Total no. of detected eyes	Proper eye detection (%)
1	4	4	-	-			
2	3	2	-	1			
3	1	1	-	-			
4	4	3	-	1			
5	6	4	2	-	40	31	77.5
6	4	3	-	1			
7	4	3	1	-			
8	5	3	-	2			
9	4	-	-	4			
10	5	5	-	-			

After the detection of the eye corners from all the other detected corners, the eye region is extracted from the face image and stored in the Eye Database. Some sample images of the extracted eyes along with the eye corner distance have been shown in Table 3.

Table 3. Sample images of the extracted eyes.

Class	1	2	3	4	5	6	7	8	10
Extracted eye region									
Eye corner distance	37	27	30	30	35	34	32	26	33

4. Conclusion and Future Work

In this paper, we have presented a technique for eye detection which is based on Harris corner detection method. This process has been performed on 40 no. of images of 10 different classes of ORL Face Database and after the eye regions are extracted, they have been stored in a Database for future reference. In future we are planning to work on automatic detection of nose and lips; and classification of all these three facial parts (including eye) may be used for person identification.

Acknowledgment

Authors are thankful to the Biometrics Laboratory of Computer Science & Engineering Department, Tripura University, Tripura, India and the Department of Information Technology, Ministry of Communications & Information Technology, New Delhi-110003, Govt. of India, Vide No. 12(2)/2011-ESD, dated 29/03/2011, for providing the necessary infrastructural facilities for carrying out this research work.

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